Volume Title: Behavioral and Distributional Effects of Environmental Policy

Volume Author/Editor: Carlo Carraro and Gilbert E. Metcalf, editors

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-09481-2

Volume URL: http://www.nber.org/books/carr01-1

Conference Date: June 11â€“12, 1999

Publication Date: January 2001

Chapter Title: Costs of Air Quality Regulation

Chapter Author: Randy A. Becker, J. Vernon Henderson

Chapter URL: http://www.nber.org/chapters/c10608

Chapter pages in book: (p. 159 - 186)

5

Costs of Air Quality Regulation

Randy A. Becker and J. Vernon Henderson

5.1 Introduction

An ongoing debate in the United States concerns the costs environmental regulations impose on industry. In this paper, we explore some of the costs associated with air quality regulation. In particular, we focus on regulation pertaining to ground-level ozone (O_3) and its effects on two industries sensitive to such regulation—industrial organic chemicals (Standard Industrial Classification [SIC] 2865–9) and miscellaneous plastic products (SIC 308). Both of these industries are major emitters of volatile organic compounds (VOCs) and nitrogen oxides (NO_X), the chemical precursors to ozone. Using plant-level data from the U.S. Census Bureau's Longitudinal Research Database (LRD), we examine the effects this type of regulation has had on the timing and magnitudes of investments by firms in these industries and on the impact it has had on their operating costs. As an alternative way to assess costs, we also employ plant-level data from the U.S. Census Bureau's Pollution Abatement Costs and Expenditures (PACE) survey.

Our prior work has found a variety of effects on industry behavior at-

Randy A. Becker is an economist at the Center for Economic Studies of the U.S. Bureau of the Census. J. Vernon Henderson is professor of economics at Brown University and a research associate of the National Bureau of Economic Research.

The authors thank the National Science Foundation for support, as well as the National Bureau of Economic Research and the Fondazione Eni Enrico Mattei. This work has benefited from the comments of conference participants as well as those of seminar participants at the Center for Economic Studies (U.S. Bureau of the Census). The opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the Bureau of the Census. All papers are screened to ensure that they do not disclose any confidential information.

tributable to environmental costs (Becker and Henderson 2000). Here we attempt to quantify some of these costs. To identify effects, we use spatial variation in regulatory stringency as well as temporal differences arising from the introduction of heightened regulation. Our previous research has shown that plant age and plant size are important determinants of who gets regulated when and how intensely, so we incorporate these elements into our analysis here as well. Our models also control for location-specific fixed effects, which is critical in this type of work. Here, we find that regulation indeed significantly increases production costs, especially for young plants, with estimates that (arguably) are higher than the expenditure data from the PACE survey suggest. Our results also show that regulation may lead plants to restrict their size, and the reasons why this might be the case are discussed. We also find that, in at least one of these two industries, investment profiles are significantly altered for plants subject to regulation, with relatively more up-front investment and less phasing-in.

In section 5.2, we offer a general overview of air quality regulation in the United States, introducing our key environmental variable and discussing some of the difficulties involved in identifying a control and a treatment group for empirical work. In section 5.3, we discuss the results from our prior research that led us to our current focus. We then turn to a description of our data in section 5.4. The three ensuing sections present results from our analyses of the size and timing of investments, regulatory costs using data from the LRD, and cost estimates using PACE data. The final section offers some concluding remarks.

5.2 The Nature of Air Quality Regulation

Each year (since 1978) each county in the United States is designated as either being in or out of attainment of the National Ambient Air Quality Standards (NAAQS) for ground-level ozone. Areas that are in *nonattainment* of this standard are, by law, required to bring themselves into *attainment* or face harsh federal sanctions. The primary way of achieving attainment is through the regulation of VOC- and NO_X-emitting sources within one's jurisdiction—particularly manufacturing plants in certain industries. As a result, these plants in nonattainment areas face much stricter environmental regulation than their counterparts in attainment areas.

For example, in nonattainment areas, plants with the potential to pollute are subject to more stringent and more costly technological requirements on their capital equipment. New plants wanting to locate in nonattainment counties (as well as existing plants undertaking major expansion and/or renewal) are subject to lowest achievable emission rates (LAER), requiring the installation of the "cleanest" available equipment without regard to cost. Existing plants in nonattainment counties, who are grandfathered from these strict requirements (at least until they update their equipment), are required to install reasonably available control technology (RACT)—usually some simple retrofitting—which is to take into account the economic burden it places on a firm. In contrast, in attainment counties, only new plants and only those with the potential to emit over (originally) 100 tons per year of a criteria pollutant are subject to regulation of their capital equipment, and the technological standard is a weaker one. Rather than LAER, large new plants in attainment counties are required to install best available control technology (BACT), which is negotiated on a case-by-case basis and is to be sensitive to the economic impact on a firm. Existing plants and small new plants in attainment areas face no specific requirements on their capital equipment.

In addition to more stringent technological requirements, nonattainment status also usually entails higher costs in other areas as well. Forced to "produce environmental quality," plants in nonattainment areas must purchase additional inputs. Additional labor is certainly required; however, "environmental production" may also call for more (and/or more expensive) materials and energy as well. Costly redesigns of production processes can also be involved. And any proposed expansion—either the construction of a new plant or the modification of an existing facility—must first be approved by environmental regulators. This permitting process can involve lengthy and costly negotiations over equipment specifications, emissions limits, and the like. The purchase of pollution offsets may also be required. Finally, plants in nonattainment areas face a greater likelihood of being inspected and fined than their counterparts in attainment areas.

As this discussion reveals, we have (at least in principle) a control and a treatment group with which to estimate the costs of regulation. In particular, given age (i.e., new vs. existing plants), we would expect capital costs, labor costs, operating costs, and so forth to be higher for plants in counties classified as being in nonattainment of the NAAQS for ozone than for plants located in counties classified as being in attainment. The reality of the situation, however, is a bit murkier than this neat dichotomy would suggest. First, within a county, regulatory scrutiny often varies by plant size. In attainment areas, large new plants are required to install BACT, while small new plants have no specific requirements. In nonattainment areas, differential treatment is de facto rather than by decree. Local regulators, who are generally resource constrained, focus their enforcement on larger (and hence more polluting) plants, while smaller plants have been slow to be classified as polluters, and once classified, may be inspected infrequently or not at all. Then, given plant age and size, regulatory treatment of otherwise similar polluters may differ from one nonattainment area to the next because of variation in state philosophies on how best to achieve attainment. Even within a state, nonattainment areas may face different degrees of regulation because they differ in the *extent* to which they are in nonattainment. Dissimilarities between attainment areas also exist: Some face a degree of regulation above what is normally required of them simply because they are in states with strong environmental agendas.

In the empirical specifications that follow, we are mindful of differences in regulatory treatment that are due to plant characteristics, such as age and size. The remaining differences, then, between attainment and nonattainment areas are "typical" differences—alert to the fact that each group itself may have some significant variation in regulatory intensity. We also note two potential qualifications that affect this interpretation of our results. First, there is the notion that plants in attainment areas may incur environmental costs "voluntarily," as opposed to being required to do so by regulators. Such plants, for example, may be reluctant to install "dirty" production equipment in this day and age for fear of protests and law suits, as well as inducing active regulation. Furthermore, for plants in many industries, dirty equipment that may still be permissible for use in attainment areas may no longer be available for purchase. Prior to the regulatory era, plants in polluting industries were mostly located in (what would become) nonattainment areas and a considerable proportion still remain there. These producers spur technological innovation and create a market for "green" production equipment, which have affected equipment choices for everyone. Therefore, plants in attainment areas may incur environmental costs that are not the result of regulation per se, but rather are the result of various other forces (social, political, technological, etc.). Our approach, therefore, of comparing plants in attainment and nonattainment areas, will not reveal the *full* costs of regulation (from comparing a world with regulation to one without regulation and these other forces), but should at least reveal a lower bound on such costs.

Our second qualification only serves to lower this lower bound even further. In particular, plants may self-select into attainment or nonattainment areas. For example, it may be the case that firms who choose to locate in nonattainment areas may, to some extent, be those who can best handle regulatory costs. Firms in attainment areas, on the other hand, may be ones for whom regulation would be particularly burdensome. This would suggest that our estimates of regulatory costs are for a select group—understating costs for the typical plant.[1] Both these qualifications should be kept in mind when interpreting the results.

1. In theory, one might control for self-selection by using plant fixed effects in modeling (rather than county fixed effects, which we use here). In practice, however, imposing plant fixed effects eliminates many young plants (since these fixed effects require each plant to appear in two censuses, at least 5 years apart), makes identification of age effects impossible, and greatly reduces sample sizes. We therefore resign ourselves to any selection bias that may be present, realizing that it will reduce our estimates of treatment effects.

5.3 Prior Findings and Current Motivation

In our previous work in this area (Becker and Henderson 2000), we investigate the effects ozone nonattainment (vs. attainment) status has had on the decisions of firms in polluting industries. In that study (described in more detail later) we focus on major VOC- (and NO_X-) emitting industries that (1) have had large numbers of plants and plant births (nationally), and (2) do not have (as) much other air pollution emissions. These industries are industrial organic chemicals (SIC 2865–9), miscellaneous plastic products (SIC 308), metal containers (SIC 3411–2), and wood household furniture (SIC 2511). In this current paper, we focus on just the first two of these. Industrial organic chemicals, as in turns out, is the heaviest polluter of all of these industries (it actually manufactures VOCs!) and has the largest average plant sizes. Miscellaneous plastic products uses VOCs in its production and has the convenient property of being the industry with the largest sample size. Plant-level data for both studies come from the 1963–92 Censuses of Manufactures.

Our current line of research expands on previous work by Henderson (1996). Prior to this, much of the literature found little effect of state or county differences in environmental regulation on firm behavior (e.g., Bartik 1988; McConnell and Schwab 1990; Gray 1997; Levinson 1996). Much of this work, however, has been based on cross-sectional data and/or methods, which has proven to be a critical limitation. In order to properly disentangle the inherent locational and productivity advantages typical of nonattainment areas from the adverse (regulatory) impacts of nonattainment status, panel data and methods are necessary, such as those used in Henderson (1996), Becker and Henderson (2000), and Kahn (1994). We, again, employ such data and methods here in this paper.

Our earlier research (Becker and Henderson 2000) yielded three key findings. First, plant births in these polluting industries (followed by the stocks of plants) have, with the advent of regulation, shifted over time from nonattainment to attainment areas, while general economic activity has not exhibited such a shift. Depending on the industry and time period one looks at, the expected number of new plants in these industries in ozone nonattainment areas dropped by 25–45 percent. The sectors targeted first and most intensely by regulators were those industries with the largest plants and, within industries, the "corporate" sector (with its larger plants) compared to the "nonaffiliate" (or single-plant firm) sector. This supports the notion that size matters in who is regulated when and how intensely.

Second, survival rates of plants in nonattainment areas, while originally the same as those in attainment areas, rose with the advent of regulation. Recall that existing plants are grandfathered from the strictest regulations (until they update or expand their operations) and are only subject to RACT requirements. New plants, on the other hand, are subject to costly LAER requirements. Existing plants, therefore, have a cost advantage over new entrants and reason to stay in business longer than they might have otherwise. Similarly, as regulations tighten over time, former new plants (with former LAER equipment) are exempt from the tightening. The net effect is better survival of existing plants in nonattainment areas and incentive to delay equipment renewal and changes in product composition. There is yet another explanation for this result. Older firms may get heavily involved in their states' regulatory process—working with regulators to formulate regulations, advocating for particular laws, and so forth. Even if the regulatory process remains without favoritism, these firms have insiders' knowledge of what their state regulators are most focused on. It may, therefore, be easier and less costly for them to meet the specifications and regulations issued by that particular state.

Third, it appears that plants in nonattainment areas, rather than phasing in investment over a 5- to 10-year period, do more up-front with less subsequent investment. In terms of sales and employment, we found that new plants in nonattainment areas started off anywhere from 25 to 70 percent larger, but after 10 years, no size differences remained. The permitting process for the construction of a new plant in a nonattainment area (as well as the proposed expansion of existing facilities) can require months of costly negotiations—involving the firm, its environmental consultants, state regulators, and the regional Environmental Protection Agency (EPA)—over equipment specifications, emissions limits, the purchase of pollution offsets, and the like. By investing all at once, these plants avoid incurring negotiation costs over and over again; moreover, they preserve their grandfathered status.

Our current paper expands on these findings in two ways. First, we revisit the issue of regulation's impact on the size and timing of plants' investments (the third key finding) by examining data on plants' capital stock formation, instead of using sales and employment data as we did before. The questions we ask here (and the methodology we employ) are similar to those in our previous paper. Namely, does nonattainment induce more up-front investment and less subsequent investment as a result of the costly negotiating and permitting process required for plant expansion under regulation? And, given that regulatory scrutiny seems to be closely related to plant size, is downsizing evident in nonattainment areas relative to attainment areas once the initial investment period of a new plant is past? Also, how does regulation impact the capital-to-labor use of plants in these industries?

The second (and major) focus of this paper is in actually quantifying regulatory costs. The birth model estimated in Becker and Henderson (2000) implies that the number of new plants in nonattainment areas drops because the net present value of profits in those areas falls. One view of the birth process is that, in any given year, there is a local supply of potential entrepreneurs to an industry in a county and a (demand) schedule of profit opportunities decreasing in the number of births. Nonattainment status shifts back the (demand) schedule of profit opportunities, moving the county down the supply curve and reducing births. The implied percentage drop in plant profits (which are unobserved) is unclear since both demand and supply elasticities are involved in a reduced-form specification of birth counts.[2]

In this paper, we look at this issue from the cost side. In particular, we ask what happens to a plant's operating costs if we move it from an attainment to a nonattainment area. We perform this experiment by comparing the production costs of plants in nonattainment counties (our treatment group) with those in attainment counties and those in existence before the advent of regulation (our control group). Since our prior work suggests that both plant size and plant age matter in regulation, we incorporate these factors into our analysis as well. And, as we mentioned earlier, this type of work suffers tremendously if inherent county characteristics are not controlled for, so we also employ county fixed effects in all our models. Given these fixed effects, the nonattainment effect is identified by differences between attainment and nonattainment counties arising from the imposition of regulation (in 1978), relative to any differences that might have existed in the preregulatory period (when there were no regulatory differences between these counties). Recall from our comments in section 5.2 that estimated cost differences between attainment and nonattainment areas are likely to represent a lower bound on *true* regulatory costs. We will see in the next section that there are additional reasons why we cannot estimate the full costs of regulation.

5.4 The Data

Our plant-level data come from the LRD, available through the Census Bureau's Center for Economic Studies. Here, we use only the quinquennial Census of Manufactures from the period 1972–92. And since we require (nonimputed) data on capital assets for both our examination of investment patterns and our estimation of cost functions, we use mainly those plants that are also in the Annual Survey of Manufactures (ASM) in those years.[3] We further eliminate any plants that are administrative record

2. Note that, even with regulation, nonattainment counties do have some births, given a local supply of entrepreneurs (with their own idiosyncracies) and local and regional demand forces.

3. Total assets (buildings and machinery together) was also asked of non-ASM plants in the 1987 and 1992 censuses. For our cost function exercises, since we are not interested in the separate components of capital stock, we also use these plants in our estimation.

cases, have their establishment impute flag set, or show signs of inactivity (i.e., have a zero value for any critical variable). We further restrict our attention to "corporate" (or "multiunit") plants. Controlling for age, these plants are much larger than single-plant firms and are therefore more likely to be regulated and exhibit regulatory effects. Their data may also be more accurate than those for single-plant firms, and they certainly account for most of an industry's output.[4] Finally, the inclusion of county fixed effects in our models requires plants to be in counties where at least one other plant-year is observed. The impact of this restriction on sample sizes is relatively slight; less than 5 percent of plants are lost as a result of this requirement. In the end, our samples contain 70–74 percent of all multiunit plants in industrial organic chemicals and 53–61 percent of all such plants in miscellaneous plastics.

In our investment regressions (in section 5.5) we use a plant's stock of real capital and its real capital-to-labor ratio as dependent variables. For these regressions we use, as our measure of real capital stock, end-of-year machinery and equipment assets (which are on an "original cost" basis) divided by capital-asset deflators constructed from Bureau of Economic Analysis (BEA) published data (see Becker 1998). Plant total employment serves as the denominator of our ratio. Here, and in our cost function regressions, plant age dummies are (generally) determined by the time elapsed since the plant's first appearance in the Census of Manufactures, regardless of its industry in that first appearance. In our empirical specifications below, we recognize three age categories: 0–4 years, 5–9 years, and 10+ years.[5]

For our cost-function regressions, a plant's total costs are defined as the sum of its salaries and wages; its costs of materials, fuels, electricity, and contract work; and the cost of "capital services." The last is calculated by multiplying beginning-of-year total assets (machinery, equipment, structures, and buildings) by an appropriate "user cost factor."[6] Note that these data from the Census of Manufactures do not subsume all of the (previously noted) costs associated with environmental regulation (e.g., fines,

4. In industrial organic chemicals, corporate plants account for about 97 percent of the industry's output. In miscellaneous plastic products, they account for about 72 percent.

5. For example, a plant in the 1972 census is 0–4 years of age if it is making its first census appearance in 1972. It is 5–9 years of age if it made its first census appearance in 1967 and 10+ years of age if it made its first census appearance in the 1963 census. The recognition of any additional age categories is not practical. Since the LRD does not contain any of the censuses prior to 1963, we are not able to distinguish between 1972 plants that are 10–14 and 15+ years of age. Excluding 1972 plants from the analyses (and using just 1977–92 plants) avoids this problem but unfortunately eliminates an important (control) group of preregulatory plants that help us identify the effects of regulation. On the opposite end, fewer age categories would not buy us any additional data. In principle, two age categories would allow us to use plants in the 1967 census as well; however, capital-asset data were not collected from these plants and therefore they are of no use to us for the types of analyses we wish to conduct here. Using three age categories, therefore, is ideal.

6. The difficulty here is that the asset information collected by the Census Bureau is on an original cost basis. It reflects the book value of assets (of various vintages and quality, etc.),

pollution offsets, and environmental consultants), which obviously affects plants in nonattainment areas more than those in attainment areas. This is yet another reason to view any estimated cost differences as a lower bound on the true cost of regulation. What will be captured here is regulation's impact on the use of labor, capital, and some of the other inputs, as well as any impact it may have on production (output). Here, total output of a plant in a given year is measured by its total value of shipments in that year, with appropriate adjustments for changes to inventory. This value of output is then divided by the industry's (national) output price index to yield a real measure of plant output. This price index, along with the industry-specific materials price index (referred to later), is taken from the NBER-CES Manufacturing Industry Database (Bartelsman, Becker, and Gray 1998).

In addition to these plant-level data, we also have information on county characteristics. In particular, we have LRD-derived, county-level measures of average manufacturing wages and total manufacturing employment, exclusive of the industry being analyzed. We also have county ozone nonattainment status, as recorded annually in the Code of Federal Regulations (Title 40, Part 81, Subsection C). Given that 1978 was the first year in which counties were designated as being in or out of attainment, the plants in the 1982 Census of Manufactures would have been the first ones to directly feel the effects of the 1977 amendments to the Clean Air Act. And since the previous year's attainment status determines the current year's regulation, we use 1981 nonattainment status for 1982 plants, 1986 nonattainment status for 1987 plants, and 1991 nonattainment status for 1992 plants.

5.5 The Size and Timing of Investments

The questions we pose in this section are (1) does regulation induce more up-front investment by plants (versus phasing-in) as a result of the (fixed)

but not necessarily their true economic value. Given the highly imperfect nature of these data, multiplying them by a *proper* user cost of capital series seems somewhat incongruous. What we have done instead is derive "user cost factors" such that capital's share of total costs in our samples (by industry and year) equals capital's share of total output (for the corresponding year and two-digit industry) in Dale Jorgenson's 35KLEM.DAT (available at http://www.economics.harvard.edu/faculty/jorgenson/ and described in Jorgenson 1990). For SIC 28 (chemicals), capital's share of total output in Jorgenson's data ranged from 15.2 percent (1982) to 21.3 percent (1987) for the 5 census years used in our study. To replicate these shares in our data for industrial organic chemicals required user cost factors ranging from 0.1495 (1972) to 0.2136 (1987). For SIC 30 (rubber and miscellaneous plastics), capital's share of total output in Jorgenson's data ranged from 4.1 percent (1982) to 6.6 percent (1972). To replicate these shares in our miscellaneous plastic products sample required user cost factors ranging from 0.0689 (1982) to 0.0979 (1972). We note that in the initial phases of this study we experimented with time-invariant user cost factors of 0.17 (e.g., a 10 percent interest rate plus a 7 percent depreciation rate) and 0.10, with results that are remarkably similar to the ones obtained using the factors computed here. We do not believe, therefore, that our results are sensitive to our treatment of the capital data.

costs involved in capacity expansion, and (2) does regulation ultimately lead to reduced plant sizes as plants seek to avoid regulatory scrutiny? Regarding the latter, plants could also downsize to reduce investment risk at any one location, in the face of uncertainty over local regulatory costs. In Becker and Henderson (1997), we explore general downsizing issues in these industries. In the miscellaneous plastics industry, we find that plants of the same age are of roughly comparable size across the generations. In the industrial organic chemicals industry, on the other hand, plants built prior to 1968 (i.e., before the 1970 amendments to the Clean Air Act) are found to be distinctly larger, at every age, than plants built after this point (i.e., those who made their first census appearance in 1972 or later). The size profiles of successive birth cohorts in the regulatory period, however, did not continue to decline. This suggests, of course, that technological rather than regulatory changes may have led to this "one-time" change in average plant size. But the issue of determining overall trends in plant sizes in this industry is complicated by the fact that there is a great deal of switching of plants into and out of the industry (in comparison with other industries). We find that, after 1972, the number of plants switching out of the industry and the average size of such plants rises quite dramatically, while the sizes of those switching into the industry actually diminishes somewhat. It is difficult, therefore, to come to any firm conclusions.

Here, rather than try to assess the general effects of regulation on plant size, we focus on the differences between attainment and nonattainment counties. Our main interest is in the effects that nonattainment status has had on plants' accumulation of real capital stock (machinery and equipment assets in particular), but we also consider possible impacts it may have had on real capital-to-labor use. We hypothesize that these two items are functions of county characteristics—wages (a cost factor), employment (a scale/demand factor), fixed effects, and ozone nonattainment status—and plant characteristics. In particular, we allow our dependent variables to be functions of plant age (which will allow us to gauge investment patterns over time) as well as age interacted with nonattainment status (which allows us to measure the differential impact of regulation). Results from these regressions are in table 5.1.

We clearly see that capital assets rise with plant age. In the industrial organic chemicals industry, relative to the base group (new plants in attainment counties), plants 5–9 years of age are 67 percent larger, those 10+ years are 97 percent larger, and those built prior to 1968 are 176 percent (0.968 + 0.793 = 1.761) larger. In miscellaneous plastics, these percentages are 45 percent, 81 percent, and 122 percent, respectively. The final percentage in each of these trios reinforces the notion (discussed previously) that plants built before 1968 (and the 1970 amendments to the Clean Air Act) are simply larger than those constructed later.

What effect does regulation have on these patterns? In industrial organic

Table 5.1 Capital Stocks under Regulation

	Industrial Organic Chemicals		Miscellaneous Plastic Products	
	ln (*K*)	*K*/*L*	ln (*K*)	*K*/*L*
Age 5–9 years	0.668**	−49.05	0.455**	−7.124
	(0.188)	(35.63)	(0.057)	(7.366)
Age 10+ years	0.968**	−103.23**	0.809**	−7.740
	(0.229)	(43.36)	(0.071)	(9.207)
Plant built before 1968	0.793**	8.57	0.406**	7.643
	(0.202)	(38.30)	(0.069)	(8.891)
Nonattainment	0.794**	82.05	0.062	4.665
	(0.267)	(50.52)	(0.088)	(11.355)
× Age 5–9 years	−0.587*	−36.07	0.089	−0.182
	(0.324)	(61.40)	(0.098)	(12.696)
× Age 10+ years	−1.046**	−79.10	−0.086	−3.055
	(0.317)	(60.03)	(0.099)	(12.781)
× Plant built before 1968	0.555**	13.72	0.120	−2.493
	(0.241)	(45.64)	(0.092)	(11.852)
County wages and employment	Yes	Yes	Yes	Yes
Year and county effects	Yes	Yes	Yes	Yes
N (counties)	1,730 (220)	1,730 (220)	7,745 (820)	7,745 (820)
Adjusted R^2	0.545	0.369	0.290	0

Note: Standard errors are in parentheses.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

chemicals, new plants in nonattainment counties are 79 percent larger than new plants in attainment counties. Plants 10+ years of age, however, are actually 13 percent smaller in nonattainment counties than similar plants in attainment counties.[7] These results support our hypotheses: Regulation induces greater up-front investment in nonattainment counties, but tempers the size of mature plants.

The story is different, however, for plants in nonattainment areas built prior to 1968. In industrial organic chemicals, these plants are actually 11 percent larger than similarly old plants in attainment counties.[8] This suggests an intriguing possibility. These old plants in nonattainment areas have various competitive advantages over new entrants—aspects of their operations are grandfathered; they are experienced players in the local regulatory process, learning long ago how to work with regulators and how to coexist with their neighbors; and so forth. These plants, therefore, may

7. $[(1 + 0.968 + 0.794 - 1.046) - (1 + 0.968)] \div (1 + 0.968) = -0.1280$, or roughly 13 percent.

8. $[(1 + 0.968 + 0.793 + 0.794 - 1.046 + 0.555) - (1 + 0.968 + 0.793)] \div (1 + 0.968 + 0.793) = 0.1097$, or 11 percent.

be in a better position to exploit the scale economies inherent in production (see section 5.6), and, given grandfathering and an exodus of competitors, they may have access to relatively large regional demands, compared to similar plants in attainment areas. As such, it may be profitable for them to operate on a scale larger than that of their attainment-area counterparts, who face a substantial number of new entrants.

Turning to the miscellaneous plastic products industry, our hypotheses are really not borne out. In this industry, after controlling for plants built prior to 1968, real capital stocks are no different between plants in attainment and nonattainment areas at different ages. Since total capital investments in this industry are so much smaller than they are in industrial organic chemicals (in any given census, the average multiunit miscellaneous plastics plant has approximately 6–7 percent of the machinery and equipment assets of the average industrial organic chemicals multiunit plant) issues of phasing-in, downsizing, and so forth may be less relevant here.[9]

We also see no significant effects of nonattainment status on real capital-to-labor use in these industries. In fact, very few coefficients in either of these two regressions are actually significant. That we find no effect of regulation on capital intensity is somewhat at odds with our later findings with the PACE data, which show, at least for industrial organic chemicals, capital expenditures relatively more affected than labor costs.

5.6 Quantifying Regulatory Costs

In this section, we compare the average total costs of production for plants in nonattainment counties to those in attainment counties. We assume that, in any period, competitive plants face a constrained cost minimization problem. We could formalize regulatory constraints in various ways, but here we will specify a very general constraint. Suppose l, k, and m are inputs of labor, capital, and materials into production; l_R and k_R are inputs of labor and capital associated with regulation (i.e., pollution reduction); w, r, and p_m are the respective factor prices (which are exogenous to the firm), and X is plant output. A plant's constrained cost minimization problem (with respect to l, k, m, l_R, and k_R) could be written as

$$(1)\qquad w \cdot (l + l_R) + r \cdot (k + k_R) + p_m \cdot m - \theta[X - X(l,k,m;\text{age})] - \lambda[R_h(l,k,m,l_R,k_R;\text{age})].$$

9. Having said that, we note that an identical regression (not reported here) on a sample that also includes single-unit firms (in addition to these multiunit plants) reveals some of the hypothesized effects. Namely, new plants in nonattainment areas were found to start with 20 percent more capital than their counterparts in attainment areas, but after 10 years, there was virtually no difference between the two groups. Why these effects might be found in the single-plant sector and not the multiplant corporate sector is puzzling.

Here, the $R_h(\cdot)$ function is the regulatory constraint, where h indexes the two possible regulatory states: attainment and nonattainment. Note that we have allowed plant age to affect both the technology of the plant as well as (and more critically) regulatory stringency. This minimization problem, with its choice of inputs, yields a reduced-form total cost that is a function of factor prices, output, and age. Dividing through by output and invoking linear homogeneity of cost functions, we are left with the following reduced-form average total cost function:

$$ATC/p_m = f_h(w/p_m, r/p_m, X, \text{age}). \tag{2}$$

We have let our needs and interests dictate our empirical formulation of equation (2). Since we are not interested in estimating the elasticities of substitution between factors, a translog specification is too much. And a simple Cobb-Douglas cost function, which is linear in output, is also inappropriate for our purposes. We therefore choose a log-quadratic formulation, which allows for a classic U-shaped average total cost function:

$$\ln\left(\frac{ATC_{ijt}}{p_{m_t}}\right) = \alpha_0 \cdot \ln\left(\frac{w_{jt}}{p_{m_t}}\right) + \sum_{s=0}^{5} D_{sit} \cdot [\beta_s + \gamma_s \cdot \ln(X_{it}) + \delta_s \cdot \ln(X_{it})^2] + d_t + C_j + \varepsilon_{ijt}, \tag{3}$$

where

D_{0it} = 1 for all plants.
D_{1it} = 1 if plant i is 5–9 years old in year t; 0 otherwise.
D_{2it} = 1 if plant i is 10+ years old in year t; 0 otherwise.
D_{3it} = 1 if plant i is in a nonattainment county in year t; 0 otherwise.
D_{4it} = 1 if plant i is in a nonattainment county and 5–9 years old in year t; 0 otherwise.
D_{5it} = 1 if plant i is in a nonattainment county and 10+ years old in year t; 0 otherwise.

Note that the average total cost of plant i in county j at time t is a function of output, output squared, year effects (d_t), county fixed effects (C_j), and a contemporaneous error term (ε_{ijt}) that is independently and identically distributed. Wages (w_{jt}), as we discussed earlier, are average manufacturing wages in the county, exclusive of the industry being analyzed. Since we are not interested in factor price coefficients per se, we have taken some liberties with respect to the other two factor prices. We assume perfect capital markets, such that all plants in an industry in a given year face the same price of capital. This, then, is captured by our year effects (d_t). Our material prices (p_m), which come from the NBER-CES Manufacturing Industry Database, vary only over time (within an industry). We can either assume that the price of materials is the same for all plants within an industry within a year or, if we believe that there may be spatial variation in such prices, to the extent that these price differences are constant over time, spatial differences are captured by our county fixed effects (C_j). What we are most interested in here is the shape of the cost curve and how it changes with age and attainment status. To this end, we have included a series of dummy variables (D_{sit}), which are interacted with the intercept, output, and output squared. These terms allow the shape to differ for six categories of plants (three age categories times two states of regulation).

The results of these regressions are given in table 5.2. Note that all the coefficients on the U-shaped structure are statistically significant, with two exceptions in miscellaneous plastics where the coefficient on nonattainment × output has a t-statistic of 1.584 (significance level of approximately 11 percent) and the coefficient on nonattainment × output^2 has a t-statistic of 1.189 (significance level of approximately 23 percent). This poses a problem for evaluating the results for the plastics industry, which is why we focus mostly on industrial organic chemicals in our remaining discussion. In and of themselves, these regression coefficients are not very interesting. These point estimates, however, are necessary for the exercises that follow.

First, for each industry, we use the estimated coefficients to calculate the level of plant output that minimizes average total cost (ATC), for each of the six categories of plants. Every situation in each of the two industries happens to be characterized by a U-shaped ATC function (i.e., a negative linear term and a positive quadratic term). For young plants in attainment areas (the "all plants" category) in the industrial organic chemicals industry, for example, the minimum of the average cost curve occurs at $(1.192994 \div [0.0622169 \times 2])$, which equals 9.587. (Recall that output and costs are both measured in natural logs.) For industrial organic chemical plants that are 10+ years old and in nonattainment counties, minimum average total cost is achieved at $\{(1.192994 - 1.078772 - 1.030363 + 1.214576) \div [(0.0622169 - 0.0588917 - 0.0538479 + 0.0632474) \times 2]\}$, which equals 11.727. Table 5.3 contains the cost-minimizing level of output for all categories of plants in both industries. We will return to a discussion of these later.

Next, we take these cost-minimizing levels of output, plug them back into the estimated cost functions, and calculate cost differentials between comparable plants in attainment and nonattainment areas, operating at their respective minimum ATCs. For example, the cost differentials for young plants in the industrial organic chemicals industry is $\{-4.751786 - [(1.192994 - 1.030363) \times 9.7162\ldots] + [(0.0622169 - 0.0538479) \times (9.7162\ldots)^2]\} - \{-(1.192994 \times 9.5873\ldots) + [0.0622169 \times (9.5873\ldots)^2]\} = 0.1770$, or 17.7 percent (given costs and output are in natural logs). Table 5.4 contains the cost differentials computed for this and all

Table 5.2 Average Total Cost Functions

	Industrial Organic Chemicals	Miscellaneous Plastic Products
ln(Output)	−1.193**	−0.319**
	(0.122)	(0.051)
ln(Output)^2	0.062**	0.015**
	(0.007)	(0.003)
Age 5–9 years	−3.594**	−0.658*
	(1.116)	(0.338)
× ln(Output)	0.850**	0.165**
	(0.231)	(0.081)
× ln(Output)^2	−0.048**	−0.010**
	(0.012)	(0.005)
Age 10+ years	−4.802**	−0.931**
	(0.817)	(0.297)
× ln(Output)	1.079**	0.223**
	(0.168)	(0.069)
× ln(Output)^2	−0.059**	−0.012**
	(0.009)	(0.004)
Nonattainment	−4.752**	−0.734**
	(0.998)	(0.367)
× ln(Output)	1.030**	0.143
	(0.216)	(0.090)
× ln(Output)^2	−0.054**	−0.007
	(0.012)	(0.006)
× Age 5–9 years	4.908**	1.282**
	(2.263)	(0.604)
× ln(Output)	−1.144**	−0.308**
	(0.462)	(0.143)
× ln(Output)^2	0.064**	0.018**
	(0.023)	(0.008)
× Age 10+ years	5.625**	1.815**
	(1.252)	(0.487)
× ln(Output)	−1.215**	−0.391**
	(0.258)	(0.115)
× ln(Output)^2	0.063**	0.021**
	(0.013)	(0.007)
Wages, year, and county effects	Yes	Yes
N (counties)	1,847 (233)	8,878 (881)
Adjusted R^2	0.232	0.231

Note: Standard errors are in parentheses.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 5.3 Plant Output That Minimizes ATC (natural log)

	Attainment Areas	Nonattainment Areas
Industrial Organic Chemicals		
Young plants (0–4 years)	9.587	9.716
Plants 5–9 years old	12.459	9.600
Plants 10+ years old	17.175	11.727
Miscellaneous Plastic Products		
Young plants (0–4 years)	10.425	10.077
Plants 5–9 years old	13.719	9.516
Plants 10+ years old	16.166	10.163

Table 5.4 Cost Differentials between Plants in Nonattainment Areas and Attainment Areas Operating at Minimum ATCs

	Industrial Organic Chemicals	Miscellaneous Plastic Products
Young plants (0–4 years)	+17.7	+4.3
Plants 5–9 years old	+9.9	+8.6
Plants 10+ years old	+10.4	+11.2

Note: In percentage by which ATC in nonattainment areas exceeds that in attainment areas.

other comparisons. Here (and throughout) *differentials* will be defined as the percentage by which costs in nonattainment areas exceed those in attainment areas. These are, therefore, expected to be positive.

The results in table 5.4 indicate that costs are indeed higher for plants in nonattainment areas compared to those of similar age in attainment areas. In industrial organic chemicals, young plants in nonattainment areas experience costs 17.7 percent higher than their counterparts in attainment areas. The difference for older plants, although lower, is still quite considerable, at roughly 10 percent. This lower cost differential for older plants is consistent with the notion (discussed earlier) that regulatory requirements are stricter for new (as opposed to existing) plants. In the miscellaneous plastic products industry, production costs are also found to be more expensive for plants in nonattainment counties, but the pattern is the reverse. Young plants in nonattainment areas are found to have costs that are 4.3 percent higher than their counterparts in attainment areas, while plants 5–9 years old in nonattainment areas have 8.6 percent higher costs and plants 10+ years old have 11.2 percent higher costs. But again, the precision and accuracy of these estimates are compromised by the two statistically insignificant cost function coefficients used in their calculation. Nonetheless, all these results point in the same direction: Nonattainment status leads to higher operating costs for plants in these industries.

Table 5.5 Industrial Organic Chemical Plant Output That Minimizes ATC, Average ln(Output), and ln(Average output)

	Attainment Areas	Nonattainment Areas
Young plants (0–4 years)	9.59, 9.16, 10.20	9.72, 9.28, 10.61
Plants 5–9 years old	12.46, 9.96, 10.94	9.60, 9.63, 10.57
Plants 10+ years old	17.18, 10.75, 11.62	11.73, 10.63, 11.77

A number of issues are raised by our analysis, and we focus on the industrial organic chemicals industry to explore them. First, one may ask why outputs that minimize ATCs might vary by age. As table 5.3 reveals, cost-minimizing outputs grow as plants age (although the growth is not always monotonic). Why do young plants minimize ATC at lower levels of output? It is probably not the case that young plants have technologies that dictate smaller plant sizes. Arguably, some sort of learning process is taking place. Young plants perhaps do best starting off small because they can only handle a simple organizational structure and a smaller scale of operation. As they gain experience, however, and learn more about their local factor (labor and material) markets, they expand. For plants in attainment areas (which show the largest growth in cost-minimizing output!), there is an additional reason for starting out small. Recall that if such plants start out too big, they may be subject to somewhat costly BACT requirements, whereas if they start out small they face no regulation. These small (initially) unregulated plants may then expand as they learn more about their local regulatory environment and, in particular, as they learn from other plants in the area how to best handle (or avoid) regulation. For plants in nonattainment areas, which exhibit smaller changes in cost-minimizing output, there are reasons (discussed previously) for not phasing in investments in this way.

Another issue, revealed in table 5.5, is that the output of the average plant can be far smaller than the level of output that minimizes ATC. There are a few reasons why this might be. It may be the case that regional goods markets are imperfectly competitive, leading firms to exercise some monopoly power (hence, production shy of cost-minimizing output). Risk avoidance behavior (to reduce exposure) may also lead firms to invest less than the amount necessary to minimize average total cost. Having said that, however, we note that the differences between actual and cost-minimizing output in attainment areas is absolutely enormous. For plants 5–9 years old in the industrial organic chemicals industry, the level of output that minimizes ATC (12.46) is approximately 1.76 standard deviations from the average ln(Output) of 9.96, and the gap for plants 10+ years of age is even larger! What is limiting the size of these plants? The obvious suggestion is regulation, or more specifically, the threat of regulation. If one believes these particular extrapolations out to the cost-minimizing levels of output, there are (virtually) decreasing average total costs throughout. Plants in attainment areas do not generally grow to these sizes because at some point they will attract attention from regulators, they will be sued by local interest groups, or they may even (single-handedly) pollute their counties into nonattainment. There are, therefore, regulation-related constraints even on these "unregulated" plants (that are not reflected in production costs). The plants that do grow to these sizes may be in lax states, where plants in attainment areas really are left alone—that is, areas that truly are devoid of *effective* regulation.

The oldest category of plants in attainment areas also contains two distinct groups: those built before the regulatory era (say, the 1970 amendments to the Clean Air Act) and those built after. Recall that we acknowledged this distinction (i.e., pre- and post-1968 plants) in our investment regressions. Attempts to control for this separate group of plants here in our cost functions result in coefficients insignificant at the 5 percent level. However, the coefficients (imprecise as they are) suggest that plants built before 1968 have much larger cost-minimizing levels of output than other plants 10+ years old. The estimates suggest that those pre-1968 plants could operate at much lower costs in attainment areas if they operated at a large scale—large enough to be regulated, but much less severely so than they would be in a nonattainment area. Post-1968 plants that are 10+ years old, on the other hand, operated at about the same costs in attainment and nonattainment areas. (Differentials for young plants and those 5–9 years old are unaffected by this reformulation.) All this might suggest that large pre-1968 plants in attainment areas, as grandfathered players with extensive experience, reap considerable advantages. Having said that, however, we note that it is still the case that very few of these plants operate at even a reasonable fraction of cost-minimizing output. We are, therefore, left with our same conclusion: Plants in attainment areas stay small to avoid triggering regulation.

How do differences between the *estimated* cost-minimizing levels of output and the *actual* levels of plant output affect the cost differentials computed in table 5.4? To see, we repeated the exercise using, instead, average ln(Output) and ln(Average output). The results of these (and our previous) computations for the industrial organic chemicals industry are contained in table 5.6. The cost differentials for young plants are fairly insensitive to the output measure chosen. Using average ln(Output), young plants are found to have costs 16.7 percent higher in nonattainment areas, compared to their counterparts in attainment areas. Using ln(Average output), this difference was found to be 16.0 percent. Originally, using ATC-minimizing output, we found a cost differential of 17.7 percent. For the older categories of plants, the results are less comparable across output measures. Using average ln(Output), cost differentials all but disappear for plants over 5 years old (+1.3 percent and −1.8 percent). With ln(Average output), plants 5–9 years old are found to have costs 9.0 percent higher in nonat-

Table 5.6 **Cost Differentials between Industrial Organic Chemical Plants in Nonattainment Areas and Attainment Areas**

	Minimum ATC	Average ln(Output)	ln(Average output)
Young plants (0–4 years)	+17.7	+16.7	+16.0
Plants 5–9 years old	+9.9	+1.3	+9.0
Plants 10+ years old	+10.4	−1.8	+0.2

Note: In percentage by which ATC in nonattainment areas exceeds that in attainment areas.

tainment areas (vs. 9.9 percent, using cost-minimizing output), but the differences virtually disappear (+0.2 percent) for plants 10+ years old. All of these estimates, however, recalling our earlier discussions, are likely to represent lower bounds on the true costs of regulation. If nothing else, they uniformly indicate that regulation is most burdensome for new (rather than existing) plants.

5.7 An Alternative Approach

Instead of quantifying the costs of regulation by inferring it indirectly from a plant's total costs (which we did in the previous section), we could also, in principle, examine directly the environmental costs incurred by the plant. The Census Bureau's PACE survey, for example, asks manufacturing plants about their capital expenditures and operating costs associated with various environmental efforts. This survey, however, has been criticized for potentially missing a large portion of environmental expenses (see Jaffe et al. 1995 for a discussion). It is generally the case that plants do not keep special track of their expenditures on environmental protection. These data therefore must be estimated. Capital expenditures of the *end-of-line* variety (e.g., scrubbers, filters, and precipitators) are rather straightforward to estimate, since these items are easily recognized and their sole purpose is pollution abatement. However, when capital expenditures are of the *production process enhancement* type (e.g., the installation of new equipment that both improves production efficiency and reduces air emissions) the task is much more difficult.

In these instances, survey respondents are asked to "estimate the pollution abatement portion [of such projects] as the extra cost of pollution abatement features in structures and equipment (i.e., your actual spending less what you would have spent without the pollution abatement features built-in)" (U.S. Census Bureau 1994, A-12). The Census Bureau acknowledges that "interviews with survey respondents indicate that estimating such an incremental cost is difficult in many instances," if not impossible (1994, 4). In 1992, the following "special instructions" were added to the survey form to help respondents in particularly difficult cases:

> Do *not* include any of the project cost *unless* the primary purpose is environmental protection. If the primary purpose of the project is environmental protection, report the whole production process enhancement project expenditure. . . . *Caution:* A project with the primary purpose of improving production efficiency may include pollution abatement features added to meet legal requirements. Since the primary purpose of such a project is still not environmental protection, do not report *any* of the production process enhancement. (1994, A-12)

Given these guidelines, and the last two sentences in particular, it is not clear whether any of the costs of production equipment meeting strict LAER standards, for example, will be attributed to environmental protection and reported in PACE, especially in the absence of an obvious baseline.

Concerns also apply to operating expenses. The salaries and wages of a plant's environmental staff are rather easily accounted for, but what of a production team that spends a small but nonzero amount of time on various environmental tasks or of plant management who must also spend a fraction of its time and effort on environmental issues? Are these costs captured in PACE? Similarly, the cost of "materials, parts, and components that were used as operating supplies for pollution abatement, or used in repair or maintenance of pollution abatement capital assets" (U.S. Census Bureau 1994, A-10) might be easy to estimate, but what about the "incremental costs for consumption of environmentally preferable materials and fuels" or the "fuel and power costs for operating pollution abatement equipment" (A-9)? Surely these are not easy items to calculate, even for the most talented and organized (and patient) of plant staffs. Apart from the potential underreporting of capital expenditure and operating costs, there are certainly other potential costs that PACE makes no attempt to capture. For example, adverse impacts on plant output, either from the outright stoppage of production (e.g., to install pollution control devices) or through the loss of operational flexibility (to comply with certain regulatory requirements). All these factors argue for the approach we used in section 5.6, where environmental costs (and related effects) are subsumed by total plant costs (and output).

Nevertheless, we conducted some rudimentary analysis of our two industries using plant-level data from the 1992 PACE survey linked to 1992 Census of Manufactures (CM) data from the LRD. Only a relatively small sample of manufacturing plants are actually asked to complete the PACE survey in any given year (e.g., approximately 17,000 in 1992), focusing disproportionately on large (and hence older) plants and plants in polluting industries. After eliminating plants with imputed data (in either the PACE, the CM, or both), as well as other suspicious cases, we are left with approximately 15 percent of all plants in the industrial organic chemicals industry in 1992 and about 4.5 percent of all plants in the miscellaneous

Table 5.7 Costs of Air Pollution Abatement Relative to Total Costs and Expenditures (%)

	Industrial Organic Chemicals	Miscellaneous Plastic Products
Capital expenditures[a]	6.8 (6.9)	1.9 (1.6)
Labor costs	1.8	0.1
Operating costs	0.9	0.2

[a] Figures in parentheses are based on published totals.

plastic products industry. This is about one-third the industry coverage we had in our previous cost-function exercises. And young plants, a segment we found to be particularly affected by regulation in section 5.6, are underrepresented here in our PACE-LRD samples. In industrial organic chemicals, only 7 percent of our sample consists of young plants (compared to 23 percent of the 1992 population in this industry), and in miscellaneous plastics, 13 percent are young plants (compared to 35 percent in the 1992 population). In the previous section, using just multiunit plants from the period 1972–92, young plants accounted for 15 percent and 26 percent of our samples, respectively, compared to the 16 percent and 30 percent in the universes from which they were drawn. These differences in sample sizes and composition, as well as in the time period covered, should be kept in mind when comparing the results here to the ones presented before. In particular, an unfortunate consequence of the limited number of young plants we have here is that we are not able to properly distinguish separate age effects in the following.

Table 5.7 contains some basic statistics for our sample of plants. Specifically, we present the share of total plant capital expenditures, labor costs, and operating costs (in 1992) directly attributable to air pollution abatement activity. These shares are computed by comparing PACE and CM responses to questions on capital investments; salaries and wages; and the costs of labor, materials, energy (electricity plus fuels), and contract work. Note that operating costs as defined here (as opposed to the definition we used in the previous section) do not include the costs of capital services (essentially because we do not have data on the stock of pollution abatement capital equipment). Perhaps most striking here is that expenditures on air pollution abatement in these industries appear to be fairly low. Air pollution capital expenditures in industrial organic chemicals only account for approximately 6.8 percent of total capital expenditure in our sample of plants (6.9 percent based on published totals). In plastics, this number is less than 2 percent. The shares of plant labor costs and operating costs accounted for by air pollution concerns in industrial organic chemicals are 1.8 percent and 0.9 percent, respectively. In miscellaneous plastics, these shares are negligible.

Table 5.8 Nonattainment Coefficients from Regressions of PACE-to-Total Ratio on ln(Output), ln(Age), Multiunit Dummy, and County Nonattainment Status

	Industrial Organic Chemicals	Miscellaneous Plastic Products
Capital expenditures	0.038*	0.006
	(0.021)	(0.004)
Labor costs	−0.001	0.000
	(0.003)	(0.000)
Operating costs	−0.000	0.001
	(0.002)	(0.001)
N	135–141	571–586

Note: Standard errors are in parentheses.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

While the impact of regulation generally appears to be much smaller here than we found before, a direct comparison is not possible given the aforementioned difference in the way operating costs are measured. We therefore instead turn to a comparison of costs between plants in attainment and nonattainment areas, using the three cost measures that we do have here. In particular, we run simple ordinary least squares (OLS) regressions, where our dependent variable is a plant's ratio of air pollution abatement expenditures (capital investment, labor costs, or operating costs) to total plant expenditures (in those same categories). Our explanatory variables include plant output, plant age, a multiunit dummy, and county ozone nonattainment status. The nonattainment coefficients from these regressions are reported in table 5.8. Only relative capital expenditure on air pollution abatement in industrial organic chemicals is significantly higher in nonattainment areas than it is in attainment areas, with a difference of almost 4 percent. All the other nonattainment coefficients are statistically insignificant and very close to 0.

These estimates obviously suggest much lower regulatory costs than we were finding with our cost-function approach in the previous section. This might be evidence of the long-held belief that PACE misses a substantial portion of environmental expenditures. The potential limitations of this survey (noted before) would obviously understate costs much more for plants in nonattainment areas than for those in attainment areas, narrowing the estimated gap between the two groups. Our earlier caveats, regarding possible self-selection as well as voluntary environmental expenditures, also apply here—serving to narrow this gap even more. And we note again that our results in table 5.8 do not (because we really cannot) distinguish regulatory effects by age of plant. Given our previous results, indicating that young plants are most affected by regulation, and given that the PACE sample is actually weighted toward older plants, differences in cost estimates may also (to some extent) be due to differences in sample composition. That this potentially heavily affected group is underrepresented in PACE obviously also has potential implications for the aggregate statistics published from this survey. The results here are suggestive, but much more work is needed in this area.

5.8 Conclusion

This paper examines the effects that air quality regulation has had on the size and timing of plant investment in two particular industries, and the cost such regulation imposes on firms in these industries. In the industry with high relative average capital assets, we find that new, regulated plants start out much larger than their unregulated counterparts, but then do not invest as much, such that after 10 years capital stocks of regulated plants are in fact smaller. This is consistent with our previous findings and highlights the substantial fixed costs involved in negotiating expansion permits, the benefits of preserving plants' grandfathered status, and the desire to keep plants small (or even downsize) in an environment where the amount of regulatory attention is often correlated with plant size. In terms of quantifying the costs of air quality regulation, our basic results show that heavily regulated plants indeed face higher production costs than their less-regulated counterparts. This is particularly true for younger plants, which is consistent with the notion that regulation is most burdensome for new (rather than for existing) plants. Unregulated plants, however, also appear to be affected by regulation (or at least the threat of regulation); we find that they produce at levels far short of the levels that minimize average total costs. This, again, demonstrates the role that plant size plays in regulatory efforts.

References

Bartelsman, Eric J., Randy A. Becker, and Wayne B. Gray. 1998. *NBER-CES manufacturing industry database.* Available at http://www.nber.org/nberces/.

Bartik, Timothy J. 1988. The effects of environmental regulation on business location in the United States. *Growth and Change* 19 (3): 22–44.

Becker, Randy A. 1998. *The effects of environmental regulation on firm behavior.* Ph.D. diss., Brown University.

Becker, Randy A., and J. Vernon Henderson. 1997. Effects of air quality regulation on decisions of firms in polluting industries. NBER Working Paper no. 6160. Cambridge, Mass.: National Bureau of Economic Research.

———. 2000. Effects of air quality regulation on polluting industries. *Journal of Political Economy* 108 (2): 379–421.

Gray, Wayne B. 1997. Manufacturing plant location: Does state pollution regulation matter? NBER Working Paper no. 5880. Cambridge, Mass.: National Bureau of Economic Research.

Henderson, J. Vernon. 1996. Effects of air quality regulation. *American Economic Review* 86 (4): 789–813.

Jaffe, Adam B., Steven R. Peterson, Paul R. Portney, and Robert N. Stavins. 1995. Environmental regulation and the competitiveness of U.S. manufacturing: What does the evidence tell us? *Journal of Economic Literature* 33 (1): 132–63.

Jorgenson, Dale W. 1990. Productivity and economic growth. In *Fifty years of economic measurement,* ed. Ernst R. Berndt and Jack E. Triplett, 19–118. NBER Studies in Income and Wealth, vol. 54. Chicago: University of Chicago Press.

Kahn, Matthew E. 1994. Regulation's impact on county pollution and manufacturing growth in the 1980s. Columbia University. Mimeo.

Levinson, Arik. 1996. Environmental regulation and manufacturers' location choices: Evidence from the Census of Manufactures. *Journal of Public Economics* 62 (1): 5–29.

McConnell, Virginia D., and Robert M. Schwab. 1990. The impact of environmental regulation on industry location decisions: The motor vehicle industry. *Land Economics* 66 (1): 67–81.

U.S. Census Bureau. 1994. *Pollution abatement costs and expenditures, 1992.* Washington, D.C.: U.S. Government Printing Office.

Comment Aart de Zeeuw

Randy Becker and Vernon Henderson are producing a series of papers on the effects of air quality regulation. This is clearly an interesting topic and the empirical results on the basis of good data sets are an especially important contribution to the literature.

The first sentence of this paper reads "An ongoing debate in the United States concerns the costs environmental regulations impose on industry," and then the paper explores some of the costs associated with air quality regulation. It might be obvious, but we must not forget that the purpose of environmental regulation is to prevent further degradation of the natural environment. It is important to know the effects and the costs imposed on industry, but it is equally important to know the benefits of improving the environment in order to be able to consider the trade-offs between the two. This paper focuses on one side of the story, but we need the other side as well in order to be able to evaluate environmental policy.

On the other hand, even if one concentrates on one side of the story, the way environmental policy is implemented can be discussed and evaluated. This aspect is somewhat missing in this paper and will be the subject of one of the sections in these comments.

A second general comment is that costs imposed on industry by environ-

Aart de Zeeuw is professor of environmental economics at Tilburg University, The Netherlands, and director of graduate studies at the CentER for Economic Research.

mental regulation are often discussed in the context of the competitiveness of that industry in the world market. It is interesting to note that the distinction between counties that are in attainment and that are not in attainment in the United States resembles the distinction between countries that have a lax and that have a strict environmental policy, but the fundamental difference is, of course, that countries do not operate under a supranational government, while counties have to comply with federal regulations. What we can learn from this will be further elaborated in another section of these comments. A conclusion follows the discussion.

Policy Implementation

The aim of the federal government is to reduce ground-level ozone O_3 by reducing volatile organic compounds (VOCs) and nitrogen oxides (NO_X), the chemical precursors to ozone, by setting standards. Becker and Henderson describe in section 5.2 of their paper how the policy is implemented. Each year, each county in the United States is designated as either being in or out of attainment of the National Ambient Air Quality Standards. Counties that are in nonattainment are, by law, required to bring themselves into attainment. This leads to the following differences. In nonattainment counties, new plants and existing ones undertaking major expansion and/or renewal are subject to lowest achievable emission rates (LAER), requiring the installation of the cleanest available equipment without regard to cost. Other existing plants are required to install reasonably available control technology (RACT). In contrast, in attainment counties, only new plants and only those with the potential to emit over 100 tons per year are subject to any regulation. These firms are required to install best available control technology (BACT), which is negotiable and sensitive to the economic impact on the firm.

This way of implementing the policy gives certain incentives to the industry involved. In fact, it does not seem difficult to predict what will happen, and this type of analysis is somewhat missing from the paper, which immediately jumps to empirical conclusions. The authors probably had some hypotheses in mind before starting the empirical work, but it helps, in my view, to understand the results when the mechanisms have been discussed first. In nonattainment counties, the incentives of the regulation are to start big in order to prevent later expansions from being subject to the LAER standard of that time, and to extend life in order to take advantage of the RACT standard on existing plants. In attainment counties, the incentive is to start small in order to prevent regulation according to the BACT standard. Given the different regulation of new plants, it is also to be expected that plant birth shifts from nonattainment to attainment counties. This last effect will reinforce the extension of the life of firms in nonattainment counties because these firms will face less competition both on local markets and in their struggle with the regulators. The empirical conclusions of Becker and Henderson are exactly in line with this, and in the interpretation of their results they come up, of course, with the same arguments. They conclude that plant birth in this industry has shifted, that the survival rate has increased in nonattainment counties, and that plants in nonattainment counties do more up-front with less subsequent investment.

As stated before, the paper does not discuss the benefits of this regulation in terms of an improved natural environment. It is clear, however, that ground-level ozone is reduced in nonattainment counties, but probably increased in attainment counties. This is fine if the damage of ground-level ozone can be characterized as of the critical-load type, which means that concentrations below a certain level are harmless. If the increase in attainment counties does not exceed the critical load, no harm is done. Otherwise, the regulation may not have been as successful as will be concluded from focusing only on the nonattainment counties.

Counties and Countries

Environmental regulations impose costs on industry. This statement will be subscribed to in general, although it was challenged by Porter (1991). His main arguments are that firms might also be triggered to reconsider their operation and to move closer to their efficiency frontier, and that firms might get a first-mover advantage when regulations also get stricter in the countries of their competitors. This discussion took place in the international context where countries that start out to internalize environmental externalities are confronted with countries that lag behind in environmental regulation. Abstracting from Porter's arguments, firms in the latter countries have lower costs and, therefore, a competitive advantage over firms in the regulated countries, driving these firms out of the world market. Alternatively, firms relocate from more regulated countries to less regulated countries. In order to counter these effects, countries have an incentive to weaken environmental regulation and lower the costs imposed on their home industry, sometimes referred to as ecological dumping. In the absence of a supranational government, countries have to enter the very complex process of international environmental agreements in order to try to get closer to the first-best solution.

Counties in nonattainment and in attainment can be compared to countries with strict and lax environmental policies, respectively. Indeed, through the shift in plant birth, the regulated industry will gradually relocate from nonattainment to attainment counties. In this case, however, the U.S. federal government has less to worry about because the industry stays within its national borders. Of course, the process leads to adjustment costs, but the federal government has no incentive for ecological dumping. The local governments of counties in nonattainment have this incentive, but they are subject to federal law and face harsh federal sanctions if they do not try to come into attainment.

The reason I make this comparison is to stress the point that here costs imposed on industry by environmental regulation are a consequence of internalizing environmental externalities and are not a concern in the context of strategic motives for the government. It is important, of course, to estimate these costs, the main aim of the paper by Becker and Henderson, but only to be able to make a proper cost-benefit analysis for setting the proper standards. It is interesting to note that the argument put forward by Becker and Henderson to explain why plants in attainment counties install cleaner equipment than needed comes close to one of the arguments in the international discussion. They argue that nonattainment counties must have a large number of polluting plants. Because a considerable proportion of these plants remains there and have to comply with the stricter standard, new technology will be developed that becomes the standard in this industry. Plants in attainment counties therefore install the same equipment, driven by technological development and not by environmental regulation. This is exactly one of the arguments put forward by Jaffe et al. (1995) to explain why, in their survey of empirical results, the competitive advantage of laxer environmental regulation does not lead to as much international relocation as was generally expected.

Conclusion

These comments are intended as a discussion of the paper in a certain context, but not to criticize the paper. In fact, the paper is well written and contains important empirical results, using new and extensive data sets, and arguments to explain the results. It is one in a series of papers; this one is mainly concerned with the estimation of cost differences between counties in nonattainment and counties in attainment. The approach is to estimate quadratic cost curves and to compare the minimal costs. The result is that these costs are higher in nonattainment counties. The paper considers two industries, industrial organic chemicals and miscellaneous plastic products, and in all the analyses the results for the first industry are somewhat stronger than for the second one. The authors also compare their indirect method with a direct method using the PACE survey, which leads to lower estimates of costs of regulation. The authors argue that this might be evidence of the long-held belief that the PACE survey misses a substantial portion of environmental expenditures.

One thing remains a bit puzzling. Becker and Henderson note that the difference between actual and cost-minimizing output in attainment areas is absolutely enormous. They give as a reason that plants in attainment areas remain small in order not to attract attention from regulators. Earlier in the paper, however, the authors argue that plants in attainment areas only start small in order to prevent regulation, which only applies to new and big plants. It is not so clear now what the final conclusion is regarding the development of plants over time. By the same token, Becker and Henderson seem to attribute downsizing of firms in nonattainment areas to the fear of regulatory scrutiny, whereas here one would think that downsizing is mainly due to higher costs. Anyway, the research program is apparently not finished and a full picture might appear in a next paper in this interesting series. To conclude, Becker and Henderson can be complimented on a nice contribution to an important topic.

References

Jaffe, Adam B., Steven R. Peterson, Paul R. Portney, and Robert N. Stavins. 1995. Environmental regulations and the competitiveness of U.S. manufacturing: What does the evidence tell us? *Journal of Economic Literature* 33 (1): 132–63.

Porter, Michael. 1991. America's green strategy. *Scientific American* 264 (4): 96.